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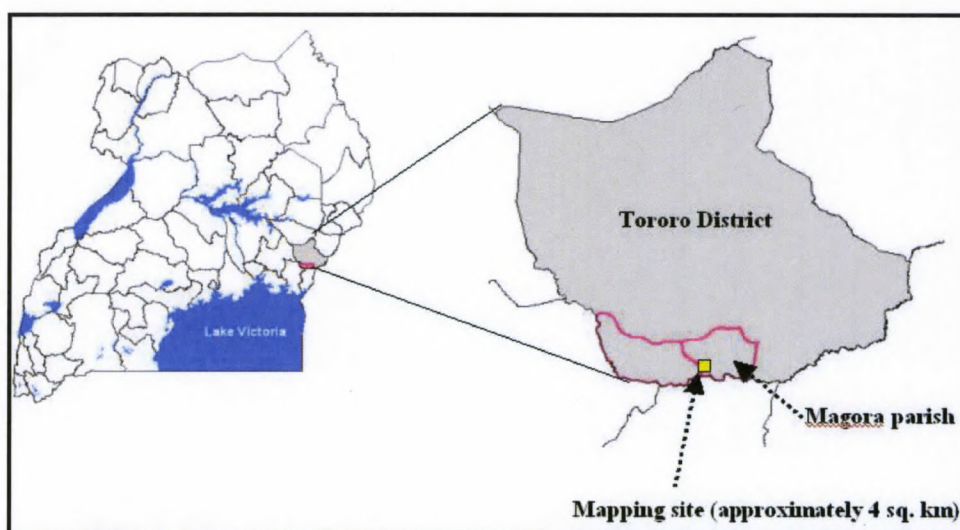
**EMMC**

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## **LARGE-SCALE MAPPING OF LAND UTILISATION TYPES USING GPS IN TORORO DISTRICT, UGANDA**

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## LARGE-SCALE MAPPING OF LAND UTILISATION TYPES USING A GPS IN TORORO DISTRICT, UGANDA

### 1.0 Background information

Generation of land cover/use maps, for geographically extensive areas and at a given scale, conventionally carried out using remote sensing techniques. According to Mather (1987) and Reed (1992), remote sensing is defined as a technique of acquiring data about a distant object without being in physical contact with the object. Remote sensing does not end with acquisition of imagery but also involves analysis of remotely sensed data to extract relevant spatial information (Short, 1998). The use of remotely sensed data (imagery) for mapping is based on the principle that radiation reflected/emitted by different landscape features is different (Figure 1.1).

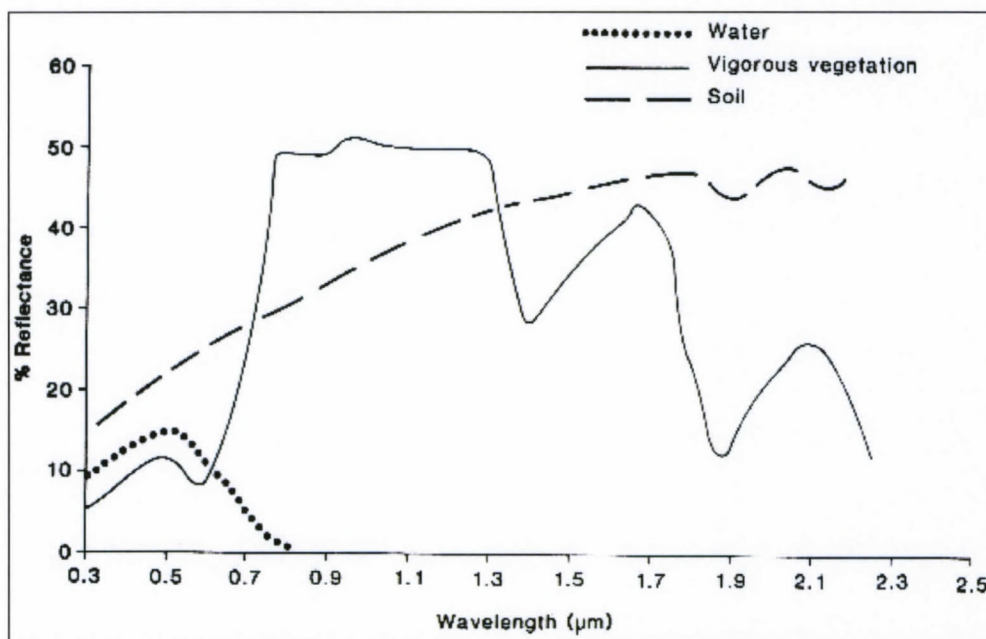


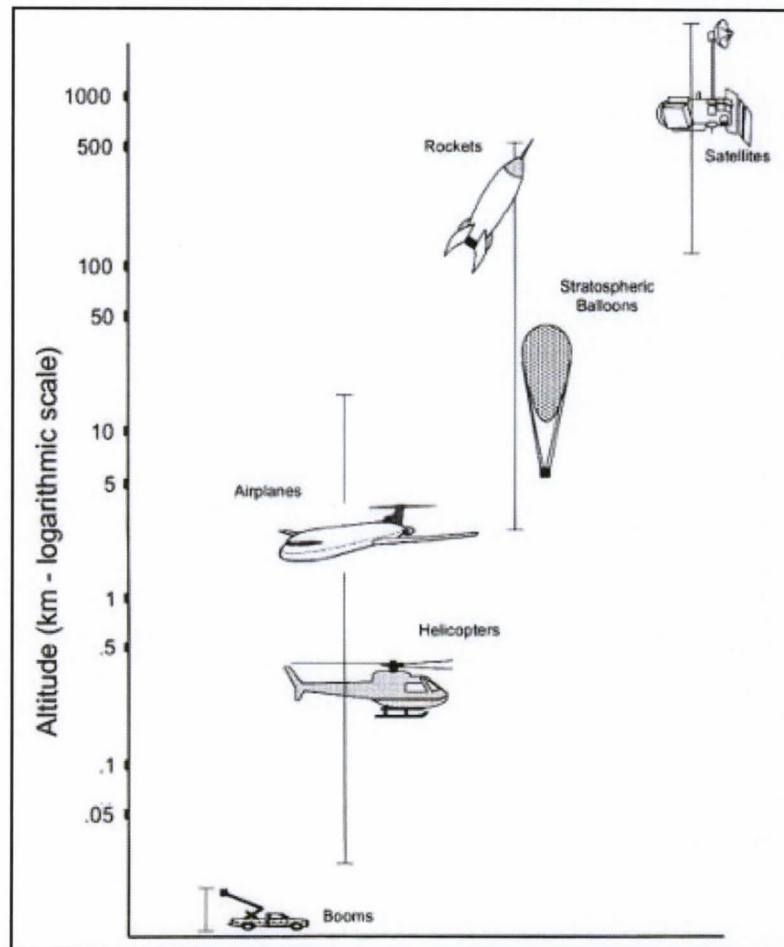
Figure 1.1 Generalised spectral reflectance curves for healthy vegetation, soil and water (source: Mather, 1987).

The differences between spectral curves (Figure 1.1) results in different spectral signatures for the three landscape objects and hence an image analyst can identify both



the boundary and identity of healthy vegetation, soil and water from imagery acquired by a variety of operational imaging sensors (Figure 1.2).

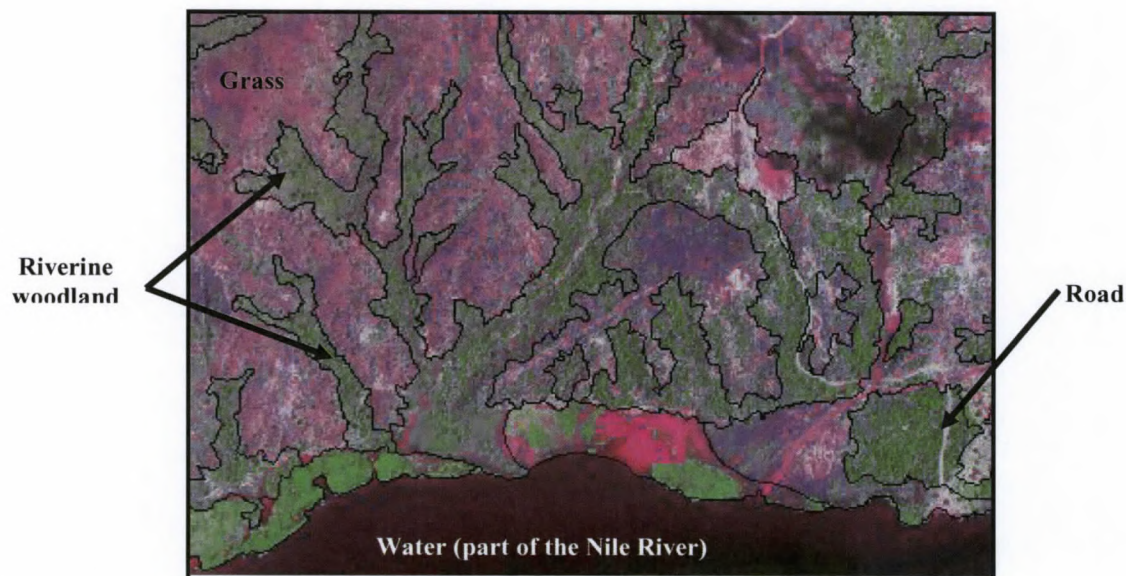
Imaging sensors are often mounted on airborne or spaceborne platforms as illustrated in Figure 1.2.



**Figure 1.2. Remote sensing platforms on which imaging sensors are mounted** (source: Wilkie and Finn, 1996).

One of the fundamental characteristics of remotely sensed data is the level of detail (spatial resolution). The spatial resolution allows an image analyst to discern the identity of different land cover/use types but also boundaries between different features. Figure 1.3 illustrates how a detailed (high-resolution) image allows the user to identify boundaries of different features of a given terrain selected from Murchison Falls National

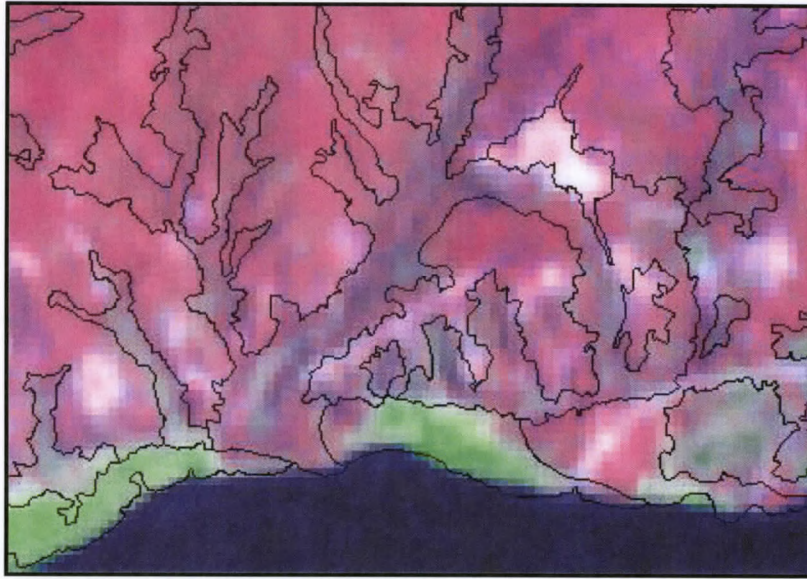
Park, Uganda. An experienced image analyst is able to identify some (not all) identities of different land cover/use type from an image. Because not all identities of land cover/use types are discernable from an image, irrespective of the resolution of such an image, remote sensing scientists often identify the type of land cover/use in a processing called ground truthing (field surveys).



**Figure 1.3A** high-resolution (detailed) image allows the user to locate boundaries of different land cover/use types from an image in a cost-effective manner. However, the identity of the land cover/use types is often established during fieldwork – ground truthing.

Conventionally, mapping of land cover/use features used to be based on high-resolution airborne photographs in both urban and rural environments. With the advent of satellite technology, imagery acquired by spaceborne sensors provides far more raw materials for mapping than aerial surveys. Spaceborne imagery has become popular because they are cost-effective. However, the level of detail (spatial) offered by traditional spaceborne sensors (such as Landsat and SPOT) is less than optimal for the production of maps at a large-scale (greater than 1:25,000). This limitation of traditional spaceborne imagery is illustrated in Figure 1.4. While the low-resolution image (Landsat TM) depicted in Figure 1.5 represents the same terrain as the high-resolution image (IKONOS), the user would find it impossible to delineate all the land cover boundaries in Figure 1.4, while it is easy to do boundary mapping in Figure 1.4.





**Figure 1.4** A low-resolution (less detailed) image does not allow the user to locate boundaries of all different land cover/use.

## **2.0 Use of GPS for mapping thematic features**

With the advent of the GPS technology, combined with the high-costs of acquiring high-resolution imagery, some organizations have adopted the use of GPS to generate detailed (large-scale maps). One such organization that have used GPS technology to generate very detailed land use maps (farm-level mapping) is the International Livestock Research Institute (ILRI) based in Nairobi, Kenya. ILRI has, over the last few years, generated several farm-level land use maps using the GPS technology in Kenya and Uganda.

There are advantages of using GPS technology for farm-level land use mapping. Boundaries of individual farms (and other natural land cover types) are traced in real time through ground digitizing. Ground identification of the different crop/crops grown in a given plot is unparalleled with any other method known. This is because image analysis is characterized by significant misclassifications, often resulting into erroneous maps. Hence GPS technology is a practical approach when carrying out detailed mapping. It is in light of these advantages of GPS technology that many are using it for thematic mapping rather than ground truthing alone.



However, there are disadvantages of GPS technology for thematic mapping. First, the geographic extent mapped must be small. How small the terrain to be mapped by the GPS technology has not yet been determined but an extensive geographic area cannot be cost-effectively mapped using a GPS, which is basically a ground mapping technique. Secondly, ground digitising of feature boundaries, using a GPS receiver, is often faced with inaccessible areas (such as swamps) and hence the placement of boundaries may be imprecise or difficult to carry out in some cases. Thirdly, ground mapping, using GPS technology or traditional surveyor's equipment, does not have a 'bird's' view of the landscape being mapped. This may lead to some ground features to be left out unmapped and hence there may be some gaps in the maps produced. Last, ground digitizing of boundaries may be a hazardous undertaking, especially in the tropics where dangerous snakes<sup>1</sup> and other harmful animals are part of most landscapes to be mapped.

In light of the tradeoffs between mapping from high-resolution imagery and using GPS technology, ILRI took a practical approach of producing farm level land use maps using the latter. This approach, enabled ILRI to identify and map small fields of a variety of crops that cannot be mapped using even the best type of imagery, SPOT 5 (2.5 m), IKONOS (4 m) and other types of high resolution imagery. The author of this report was contracted by ILRI to complete the mapping of Tororo site using GPS technology. The generated land use map for Tororo mapping site will be used, together with other several GPS-derived maps of other sites in Kenya and Uganda, for 'out scaling' to extensive landscapes using SPOT image analysis by ILRI under the FITCA Project. Whether ILRI will overcome the immense spectral overlap associated with imagery when mapping healthy vegetated landscapes remains to be seen once the project is concluded.

Prior to this contract, to map the Tororo site, ILRI staff had mapped a number of sites, in Uganda. These sites were selected in Soroti, Kamuli and Iganga Districts. There were two specific objectives of the contract between ILRI and the author of this report. These objectives were to:

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<sup>1</sup> During the Tororo site mapping exercise, one of the mapping assistants encountered a snake forcing him to abandon GPS tracking

- a) Produce a farm-level map using GPS technology; and
- b) Prepare a report on the mapping exercise.

### 3.0 Methods and materials

#### 3.1 Selection of the Tororo site

Tororo District (1,849 km<sup>2</sup>) is located in eastern Uganda and it shares its eastern border with Kenya (Figure 3.1). In 1991 national population census, Tororo's population stood at 391,977 persons, giving a population density of 212 persons/km<sup>2</sup>. According to the 2002 population census data, Tororo District has a population of 559,528, giving a current population density of 302 persons/km<sup>2</sup>. The mapping site was selected in Magora parish (Figure 2.1).

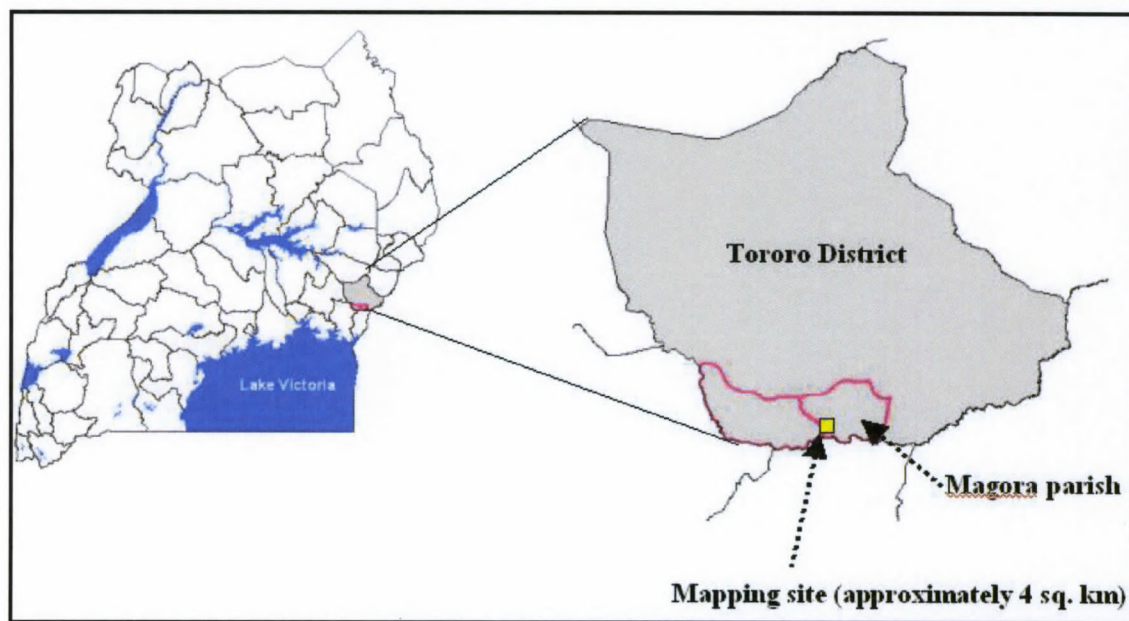


Figure 2.1 Location of Tororo mapping site within Tororo District of Uganda.

The Tororo mapping site, measuring 4 km<sup>2</sup>, was selected based on a number of factors. The major factor considered was an area where there has been FICA Project activities. Magora parish was found out to be the center of FITCA activities in Tororo District and hence the mapping site is located in the mentioned parish. Within Magora, it was decided that the mapping site be located in an area that has both farmed and natural vegetation



land cover/use types. The southwestern corner of Magora parish had both cultivated fields and natural vegetation cover (wetlands and seasonally flooded rangelands) and hence this area provided an opportunity where the mapping site was located (yellow square in Figure 2.1).

### **3.2 Materials**

The only equipment used was a hand held GPS (Garmin 12 XL). A laptop and relevant GPS software were provided by ILRI to download the tracks (boundaries of land use) and waypoints (labels of different land use types) at the end of a workday.

### **3.3 GPS training**

Use of GPS for ground mapping is a relatively straightforward exercise for those with experience in using the instrument. For those who have not used a GPS previously, one two days of training is enough to get going in the use of the instrument. Since most of the mapping assistants had never used a GPS before, an ILRI staff provided training, followed by field practice, for three days. The presence of the ILRI staff was particularly useful in sharing experience with the Ugandan mapping team, an aspect that might have minimized wastage of time in experimenting with various aspects of using GPS technology for thematic mapping. Overall, five mapping assistants were trained and one of them, pursuing an MSc (Env. Science) was given a responsibility of supervising the rest of the mapping assistants, and downloading the tracks and waypoint at the end of a mapping day.

### **3.4 GPS land use mapping**

Once the training was over, the mapping exercise began. Prior to ground digitizing of land cover/use boundaries, the four corners of the mapping site were identified. This was done by getting the coordinates of the four corners (of the mapping site) and entering them into a GPS in form of waypoints. It was then possible to walk and identify each corner of the mapping site, guided by a GPS. With the four corners identified and mapped in a GPS, the site was mapped in two phases. Each mapping phase was within a

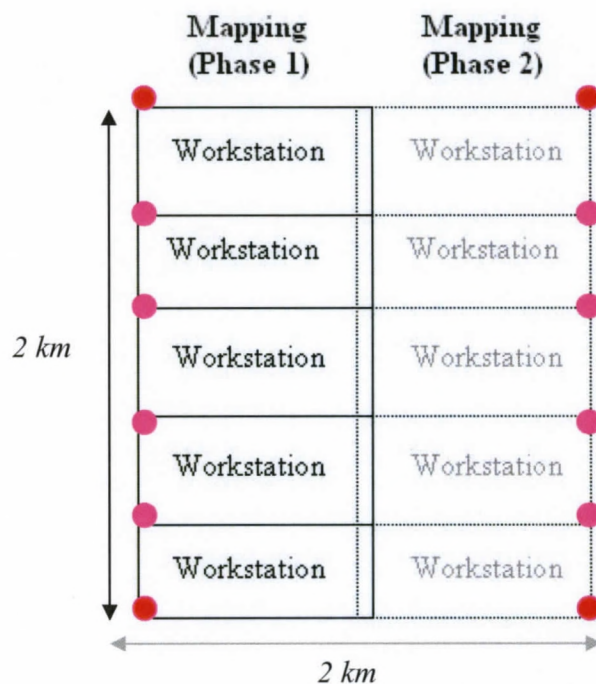


2 km by 1 km strip. Each strip was further subdivided into 5 'workstations' and assigned to one mapping assistant (Figure 3.1).

Within each workstation, a mapping assistant identified and mapped the following information layers:

- 1) Homesteads as point data;
- 2) Linear features including motorable tracks and foot paths; and
- 3) Land utilization types, field by field, as polygons.

The technique of mapping land utilization types was as follows: A mapping assistant would identify the boundaries of a field (plot) through GPS tracking. After tracking the boundaries of each plot, the tracking function of the GPS would be disabled and the mapping assistant would walk to the center of the plot. A waypoint, depicting the code for the land utilization type, would be acquired. The mapping assistant would move and track the boundaries of the next plot and capture its land utilization type.



**Figure 3.1** A hypothetical view of the Tororo mapping site indicating the corner points of the entire site (red) and workstations (purple).

At the end of each mapping day, all the GPS information would be downloaded into the laptop. The procedure of tracking boundaries of farmed and natural vegetation plots was repeated till all workstations were covered, in two phases (Figure 3.1).

### **3.5 Creation of a land use map from GPS track-lines and waypoints**

During the downloading of GPS data, the data were saved as shape files. The shape files were then imported into MicroImages TNTmips, GIS/image processing software, which allowed the author to edit the lines and convert them into polygons. Figure 3.2 shows a print of GPS boundaries and waypoints imported from shape files depicting the editing procedure in TNTmips. The final land use map has individual plots identified with a unique land cover code e.g. ML for millet.



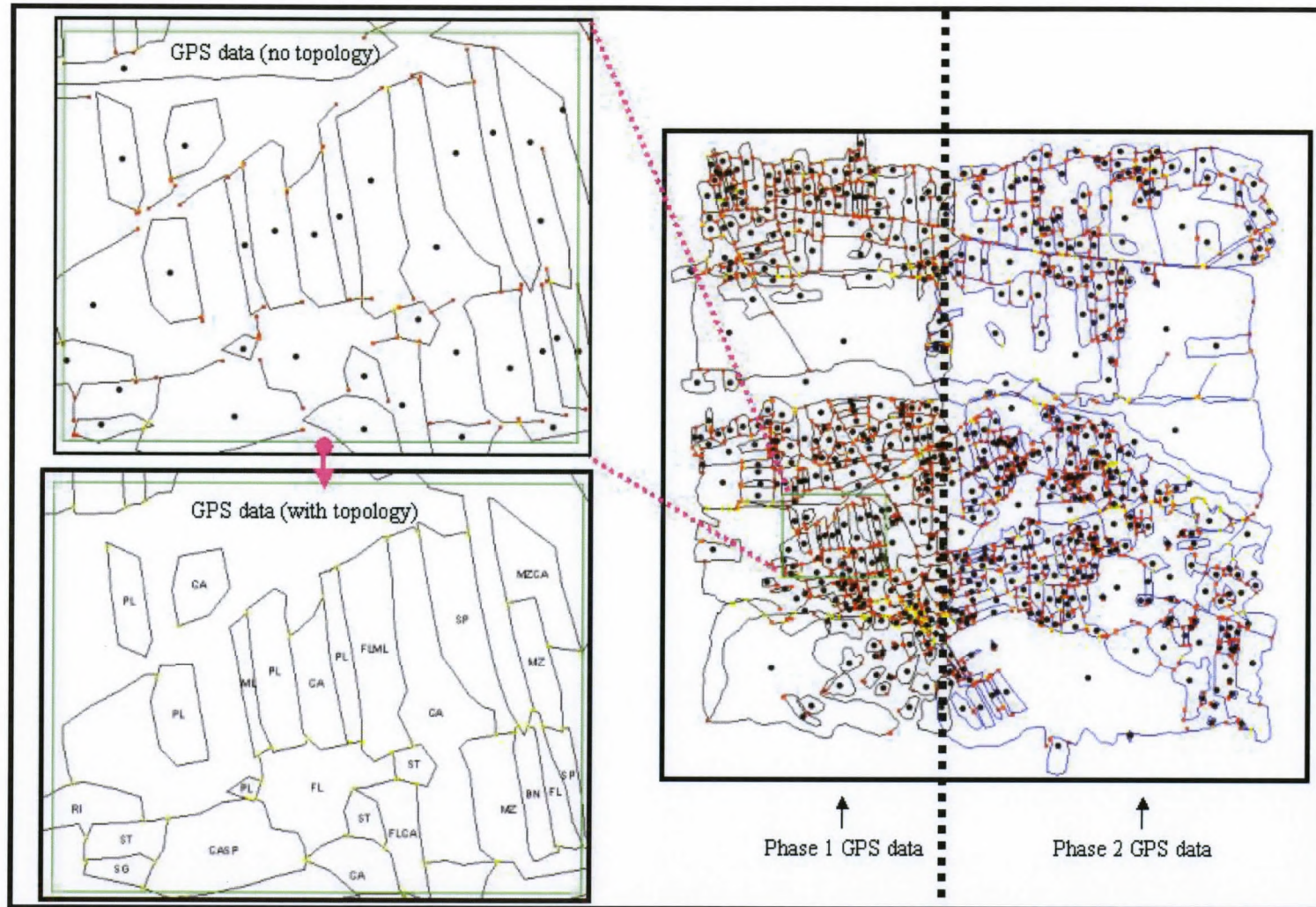


Figure 3.2 The process of creating polygons representing individual plots in TNTmips involved merging the two GPS maps made in phases 1 and 2; automatically removing undershoots and hanging lines; and linking the land cover codes to the polygon map (see 'GPS data with topology').



#### **4.0 Results**

The major output of this study was a land use map, at farm scale, and tabular extent of each land utilization type for the Tororo mapping site. The map, at farm scale, is shown in Figure 4.1, while the tabular data is shown in Annex 1. Like the rest of Uganda, Tororo mapping site is fragmented. For example, a total of 584 plots were identified and mapped. These plots comprises of about 34 different land utilization types (Figure 4.1). The most encountered land utilization types include rangelands, cassava, oxen-ploughed, fallow, settlement/home gardens, rice, millet, maize and sweet potatoes.

Natural vegetation cover, mostly used as rangelands, accounts for about 50% of the Tororo mapping site. The rest of the mapping site is fragmented into crop fields, woodlands and wetlands. Annex 1 depicts areal extent of each crop. Further information on the area extents of annual and root crops can be derived from Annex 1.

#### **5.0 Major conclusions**

Using GPS tracking, smaller areas are mapped but the method offers a practical solution, unparalleled by available methods, for obtaining actual land use data at farm level. ILRI might take comfort when it comes to 'out scaling' to large geographical areas because most boundaries obtained using GPS tracking are comparable to what would be derived from high resolution imagery such as SPOT 5 (2.5 m) or KONOS (4 m) data. The absolute advantage of GPS technology, as mentioned earlier, is that the different crops can be identified and mapped on ground. On the other hand, it appears that even from high-resolution imagery, the identity of crops cannot be established. The conclusion being that ILRI's 'out scaling' may be feasible with SPOT imagery, depending on resolution, in as far as field boundaries are concerned but probably not in the identification of the crop types. The author awaits ILRI's SPOT image analysis for this hypothesis.

This approach would allow the mapping of larger geographic per unit of money available for such an exercise. Ground GPS mapping, tracking of boundaries is a very tiresome exercise and because of this only very small areas (4 km<sup>2</sup>) could only be mapped per site



in FITCA districts of Kenya and Uganda. An MSc Student based at Makerere University will continue the research, for several other test sites, using IKONOS data (Figure 5.2) acquired in June to improve on the ILRI approach. Recommendations will be published.

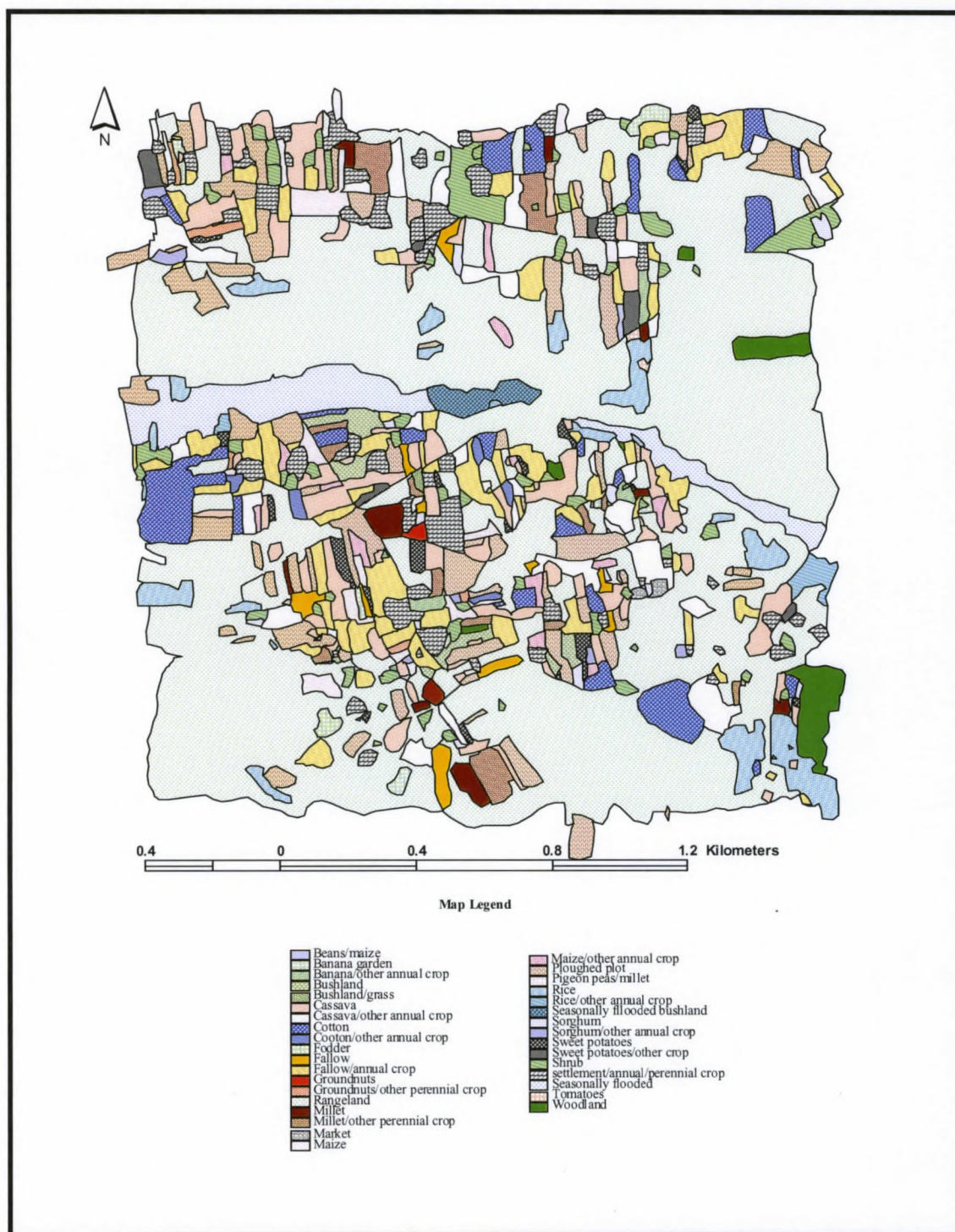


Figure 4.1 Tororo site: land utilization types – farm level



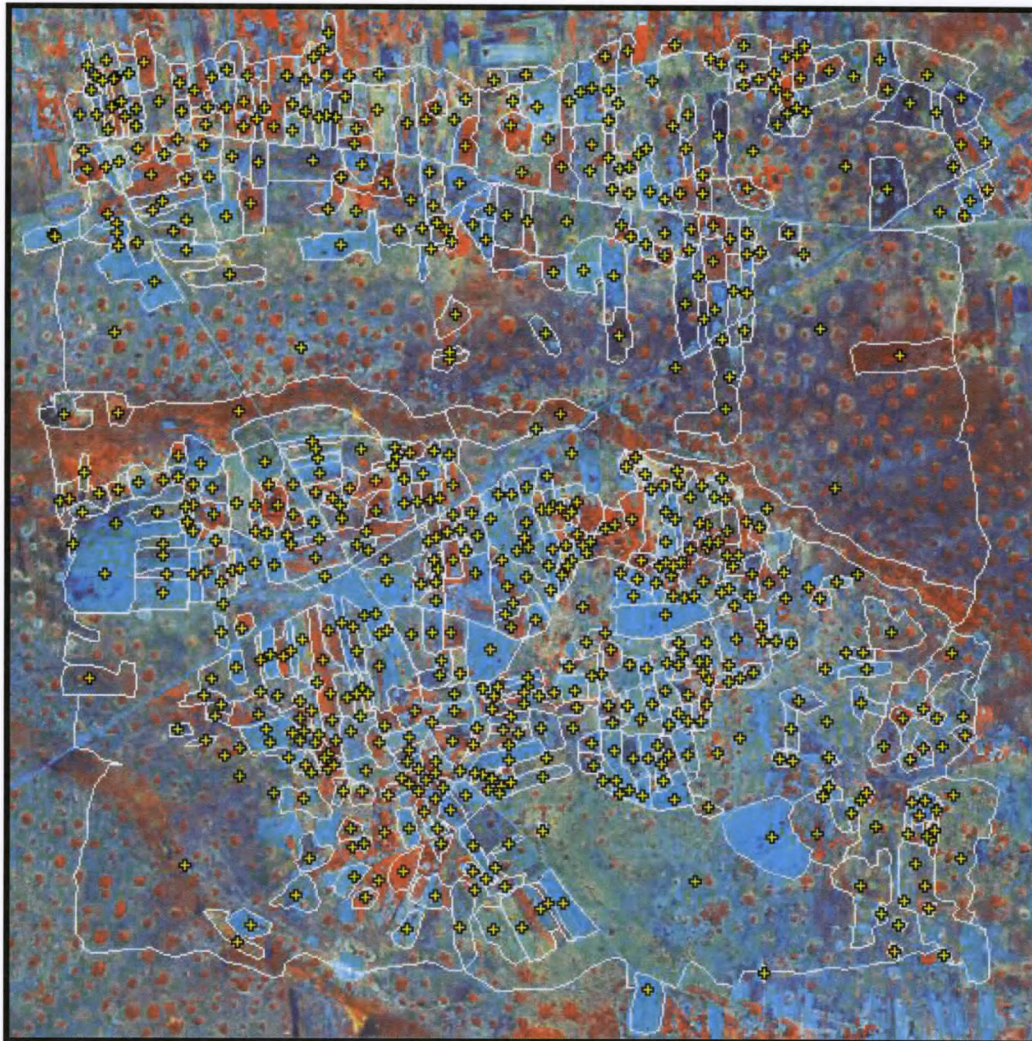


Figure 5.1 Boundaries of plots could have been identified from IKONOS (4 m) or SPOT (2.5 m) data.



# Annex 1: Tororo land utilization types

LUT Code	Land use description	Area (ha)	No. Polygons	Mean Area (ha)	% Area cover
101	Beans/maize	0.19	1	0.19	0.05
201	Banana	1.646	7	0.235	0.40
202	Banana/maize	1.092	3	0.364	0.26
301	Bush land	2.893	7	0.413	0.70
302	Bush grazing	0.167	1	0.167	0.04
401	Cassava	21.593	67	0.322	5.22
402	Cassava/ Cotton	1.016	5	0.203	0.25
403	Cassava/Groundnuts	0.688	1	0.688	0.17
404	Cassava /Millet	0.615	1	0.615	0.15
405	Cassava/ Maize	7.04	13	0.542	1.70
406	Cassava/maize/sweet potatoes	1.4343	1	1.431	0.35
407	Cassava/Rice	0.273	1	0.273	0.07
408	Cassava /Sorghum	0.212	1	0.212	0.05
409	Cassava/sweet potatoes	2.611	8	0.326	0.63
501	Cotton	14.519	24	0.605	3.51
502	Cotton /cassava	1.088	5	0.218	0.26
601	Fodder	0.443	1	0.443	0.11
701	Fallow	2.944	10	0.294	0.71
702	Fallow cassava	1.674	5	0.335	0.41
703	Fallow Millet	15.5	39	0.397	3.75
704	Fallow Millet/Rice	1.667	3	0.556	0.40
705	Fallow Millet Sorghum	0.401	2	0.2	0.10
706	Fallow Maize	0.82	5	0.164	0.20
707	Fallow Rice	0.974	4	0.244	0.24
708	Fallow sorghum	0.706	4	0.176	0.17
709	Fallow Sweet potatoes	0.98	4	0.245	0.24
801	Ground nuts	0.257	1	0.257	0.06
802	Ground nuts maize	0.961	5	0.192	0.23
901	Grazing	215.709	23	9.379	52.19
1001	Millet	3.150	10	0.633	0.77
1002	Millet /cassava	0.267	2	0.134	0.06
1003	Millet /Maize	1.992	5	0.398	0.48
1004	Sorghum	3.447	6	0.575	0.83
2001	Market	0.366	1	0.366	0.09
3001	Maize	5.023	17	0.295	1.22
3002	Maize/Banana	0.216	1	0.216	0.05
3003	Maize/Cassava	1.379	7	0.197	0.33
3004	Maize/Ground nuts	0.323	2	0.162	0.08
3005	Maize/Millet	0.434	2	0.217	0.11
3006	Maize/Sorghum	0.405	2	0.202	0.10
3007	Maize/ Sweet potatoes	0.027	1	0.027	0.01
4001	Ploughed	27.261	71	0.384	6.60
5001	Pigeon peas/Millet	0.274	1	0.274	0.07
6001	Rice	11.718	18	0.651	2.84
6002	Rice/ Cassava	1.33	2	0.665	0.32
6003	Rice/Maize	0.064	1	0.064	0.02



LUT Code	Land use description	Area (ha)	No. Polygons	Mean Area (ha)	% Area cover
7001	Seasonal flooded Wetland Bushes.	2.049	1	0.049	0.50
8001	Sorghum	1.551	14	0.111	0.38
8002	Sorghum/Banana	0.188	2	0.094	0.05
8003	Sorghum/Cassava	0.119	1	0.119	0.03
8004	Sorghum/Millet	0.052	1	0.052	0.01
8005	Sorghum/maize	0.351	1	0.351	0.08
8006	Sorghum/Sweet Potatoes	0.209	1	0.209	0.05
9001	Sweet potatoes	2.702	20	0.135	0.65
9002	Sweet potatoes/Banana	0.675	2	0.337	0.16
9003	Sweet potatoes/Cassava	0.723	2	0.361	0.17
9004	Sweet Potatoes/Groundnuts	0.25	1	0.25	0.06
9005	Sweet potatoes/ Sorghum	0.168	1	0.168	0.04
10001	Shrubs	5.246	10	0.525	1.27
20001	Settlement	6.179	59	0.105	1.50
20002	Settlement/Banana	4.384	22	0.199	1.06
20003	Settlement/Banana/Cassava	0.724	2	0.362	0.18
20004	Settlement/Cassava	2.721	8	0.34	0.66
20005	Settlement/Fallow Sorghum	0.134	1	0.134	0.03
20006	Settlement/Fruits	1.257	3	0.419	0.30
20007	Settlement/Kraal	0.448	1	0.448	0.11
20008	Settlement / Market	0.214	1	0.214	0.05
20009	Settlement /Maize	1.861	5	0.372	0.45
20010	Settlement/sweet potatoes	0.729	4	0.182	0.18
20011	Settlement/Sweet potatoes/Banana	0.697	1	0.697	0.17
20012	Settlement Woodlot	2.538	9	0.282	0.61
30001	Seasonal wetland	14.096	2	7.048	0.00
40001	Tomatoes	0.204	2	0.102	0.05
50001	Woodlot	5.038	6	0.84	1.22
<b>Total</b>		<b>410</b>	<b>584</b>		<b>96.59</b>

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